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southeast on contour lines similar to those of the older campus.

TEACHERS COLLEGE, Columbia University, will purchase, at a cost of about \$200,000, a ten-acre tract of ground overlooking Van Cortlandt Park, near the terminus of the subway. One third of the ground, a natural plateau about forty feet above the level of the park, will be used as an athletic field for the Horace Mann School. The remainder, a finely wooded plateau, about fifty feet higher, will be used for dormitories and houses for instructors.

DR. DONALD J. COWLING was installed as president of Carlton College at Northfield, Minn., on October 18.

DR. WILLIAM ARNOLD SHANKLIN will be installed as president of Wesleyan University on November 12.

MR. STEWART J. LLOYD has been made adjunct professor of chemistry at the University of Alabama.

LEON H. PENNINGTON, A.B. (Michigan, '07), Ph.D. ('09), has been appointed instructor in botany in Northwestern University.

At Wellesley College the following promotions have been made: Elizabeth Florette Fisher, B.S., from associate professor to professor of geology; Lincoln Ware Riddle, Ph.D., from instructor to associate professor of botany; Caroline Burling Thompson, Ph.D., from instructor to associate professor of zoology; Alice Robertson, Ph.D., from instructor to associate professor of zoology. With the reorganization of the department of physical education Amy Morris Homans, M.A., formerly director of the Boston Normal School of Gymnastics, becomes head of the department of hygiene and physical education. Miss Homans is joined in this work by Dr. Frederick Pratt, instructor in biology and hygiene, and Dr. Louis Collin, instructor in applied anatomy.

DISCUSSION AND CORRESPONDENCE

A REPLY TO DR. PERCIVAL LOWELL

TO THE EDITOR OF SCIENCE: In your issue of September 10, Dr. Percival Lowell alleges that I have made four mistakes in my "Introduc-

tion to Astronomy," and from these alleged mistakes as premises he draws the unique conclusion that the planetesimal hypothesis "will not work." Quite apart from the validity of the allegations, it is, to me, a novel idea in logic that errors made in trying to support a proposition become thereby "disproof of it." One might infer by this sort of reasoning that the errors of the class-room have long since destroyed all the principles of mathematics. The logic of the present case is all the more remarkable in that two of the four alleged mistakes do not occur in my discussion of the planetesimal hypothesis at all, while the two that do relate to it are really one, and it is not shown that even this one has any *critical* relations to the hypothesis.

The first point raised by Dr. Lowell is in reference to the greatest and least velocities which meteors moving in parabolic orbits can have relatively to the earth, and in this discussion, which appears eighty-three pages before I have mentioned the planetesimal hypothesis, I have made an error for which I offer no excuse. In fact, it was quite inexcusable because I had fully treated, four years earlier, in my "Celestial Mechanics" (chapter VII.), the question of the motion of an infinitesimal body relatively to that of two finite bodies describing circles, and the velocity of impact of meteors is only a special case under it. If Dr. Lowell had been as generous in citing this earlier and fuller treatment as in quoting my brief remarks in the "Introduction to Astronomy," he could have omitted a considerable part of his own paper in the *Astronomical Journal*, whose method does not differ in any essential way from my exposition of the question. In fact, it would have been necessary only to have determined the constant of integration of my equation (7), page 186. But I made a mistake, and this seems to fix a new principle in logic with a quantitative function: a mistake in expounding one proposition, if made within 83 pages of the discussion of another proposition, throws discredit on the latter.

If it were not for the new logic, Dr. Lowell's second indictment would have nothing to do

with the planetesimal hypothesis, for the alleged error occurs in a discussion of the Laplacian theory in connection with the ninth satellite of Saturn. In this, I have used only the universally accepted principle of dynamics that the moment of momentum of any mass about an axis can be changed only by a couple about the same axis. I can not accept the interpretation Dr. Lowell puts on my words, nor admit the correctness of his contention.

The statements which contain the third and fourth alleged errors do, indeed, appear in my discussion of the planetesimal hypothesis. They are quoted by Dr. Lowell, one as being "on page 480," and the other as being "from pages 478 to 481." They are, however, not only a part of the same discussion, but are in a single short paragraph on the same page (480). The third alleged error is in a formula occurring at the end of the fourth alleged erroneous statement, and gives the precise condition under which the conclusion reached is true. I suppose it is a part of the new logic to divide what is indivisible by the old logic, to invert the order, to give reference to the specific page of one, and to state simply that the other lies between certain pages; or, the last may be for rhetorical effect, as it avoids the repetition of a page-number, which might become monotonous if given more than once.

Not being as yet very familiar with the new logic, I will, with Dr. Lowell's permission, treat the statements in the order in which they occur in my book. The point in question is the effect of the collision of meteoric masses upon the dimensions of satellite orbits, particularly in the earlier stages of their development. By carefully omitting, in his last quotation, the sentences in which I have given the conditions under which my conclusions are true, he has made it appear that I have made categorical statements of universal application, and he has then found examples *outside of the conditions clearly specified* where my conclusions are not true. He then asserts that this is a "disproof" of the planetesimal hypothesis.

The associated alleged error is in the form-

ula expressing the final conditions under which my conclusions are true. Dr. Lowell's friends will regret to learn that he has been overhasty in criticizing it, considering the weighty conclusion he has hung upon his criticism. In the first place he has not quoted it quite correctly, and in the second place he starts from an erroneous equation himself. Since the linear units are not specified, the elementary principle of homogeneity of units should have shown him that the right member of his first equation is incorrect. Its left member is also inexact, due apparently to an erroneous use of the integrals of the two-body problem. If we let μ represent the mass of the satellite, his first equation should have been the inequality

$$\sqrt{\frac{1+M+\mu}{R}} - \sqrt{\frac{M+\mu}{r}} > \sqrt{1+m} \sqrt{\frac{1-e}{R-r}}.$$

Developing and omitting the negligible terms of higher order, we get precisely the formula given in my book. Consequently I stand by the conclusions reached in my book on this subject when the conditions are satisfied under which I have clearly stated they are true.

Now of the planetesimal hypothesis itself, which is much more important in the present connection, Dr. Lowell appears really to have a very excellent opinion, barring its tag and signs of parentage. In his "Mars as the Abode of Life" (1908) he says, pp. 3 and 4:

So far as thought may peer into the past, the epic of our solar system began with a great catastrophe. Two suns met. . . . It is not to be supposed that the two rovers actually struck, the chances being against so head-on an encounter; but the effect was as disastrous. Tides raised in each by the approach tore both to fragments, the ruptured visitant passing on and leaving a dismembered body behind in lieu of what had been the other. . . . Thus, what had been a sun was left alone, with its wreckage strewn about it. Masses large and small made up its outlying fragments, scattered through space in its vicinity, while a shattered nucleus did it for core.

On page 6 he says:

Thus they [the meteorites] proclaim themselves clearly fragments of some greater body. To the

sometime dismemberment of this orb, from which disintegration our sun and planets were formed, the little solitary bits of rock thus mutely witness.

In the *Atlantic Monthly* for August, 1909, in an article entitled "The Revelation of Evolution," on page 177, after commenting on and dismissing the Laplacian theory, he says, in introducing more recent work:

Without attempting here a picture of what probably took place, let me sketch a line or two of its reconstruction as they have taken shape at midnight to one watcher of the stars.

And on the following page we read:

From the information afforded us by meteorites we turn to another discovery of recent date, the recognition of the spiral nebulae. . . . Now, this spectrum [that of the spiral nebulae] is just what they should show were they flocks of meteorites—and such they undoubtedly are. They give us, therefore, the second chapter of the evolutionary history. For, from their peculiar structure, we can infer what the process was that scattered the constituents of the once compact ball whose existence the meteorites attest. They consist of a central core from which two spiral coils unfold, the starting point of the one diametrically opposite the other. Now this is what would happen had the original mass been tidally disrupted by a passing tramp. Tides in its body would be raised toward and opposite the stranger, and these would scatter its parts outward; the motion due the tramp combining with the body's spin to produce the spiral coils we see. Just as in the meteorites we have found the substances from which our solar system rose, so in these nebulae we see an evolution actually in process which may have been our own.

To those who have read the literature of the planetesimal hypothesis as it has come forth, stage by stage, during the past decade this will sound strangely familiar; and when reading Dr. Lowell's statements about the origin of meteorites, one can not help but recall Professor Chamberlin's article in the *Astrophysical Journal* eight years ago, "On the Possible Function of Disruptive Approach in the Formation of Meteorites, Comets and Nebulae." But perhaps Dr. Lowell does not read the *Astrophysical Journal*, which is edited and published not far from the home of that

"geologist out West" who "astronomically . . . is unaware that what prompted his contention, the Planetesimal Hypothesis, is mathematically unsound." The Carnegie Institution, however, is not so far "out West" that it has forfeited its claim to "be treated with respect," and in its "Year Books" of 1902 to 1907 are full expositions covering every essential element that enters into the midnight reconstruction.

From these quotations it is clear that Dr. Lowell has a real affection for the main features of the planetesimal hypothesis, and if I had not been so unfortunate as to have utterly destroyed it (according to the new logic) by the blunder in my book 83 pages before I took the hypothesis up, he might almost have reconstructed it from his own recent writings. I am wondering whether in his forthcoming book on "The Evolution of Worlds"² he will not give additional proof of his affection for the planetesimal theory, though perhaps under some other name, or in some nameless form, more congenial to that mysterious "watcher of the stars" whose scientific theories, like Poe's visions of the raven, "have taken shape at midnight."

F. R. MOULTON

¹ *Atlantic Monthly*, August, 1909, p. 181, footnote: "Even as this essay stood between pen and print a geologist out west, in a long letter to *Science*, has repeated, in reference to the facts here set forth, the old attacks on Darwin for daring to synthesize the facts; though the geologic facts are from Sir Archibald Geikie, our own Dana and DeLapparent, who should certainly geologically be treated with respect. Astronomically he is unaware that what prompted his contention, the Planetesimal Hypothesis, is mathematically unsound."

² In the advance description of this book we read: "So important scientifically is the work of Professor Percival Lowell that the announcement of a new book by him might seem to belong rather in the list of technical works than in a catalogue of general reading. Professor Lowell, however, has the rare art of conveying important and new truths in language readily intelligible to the general reader. . . . His theme is the process by which a world comes into existence, the phases through which it passes. . . ."